Summary of Model Validation Activities

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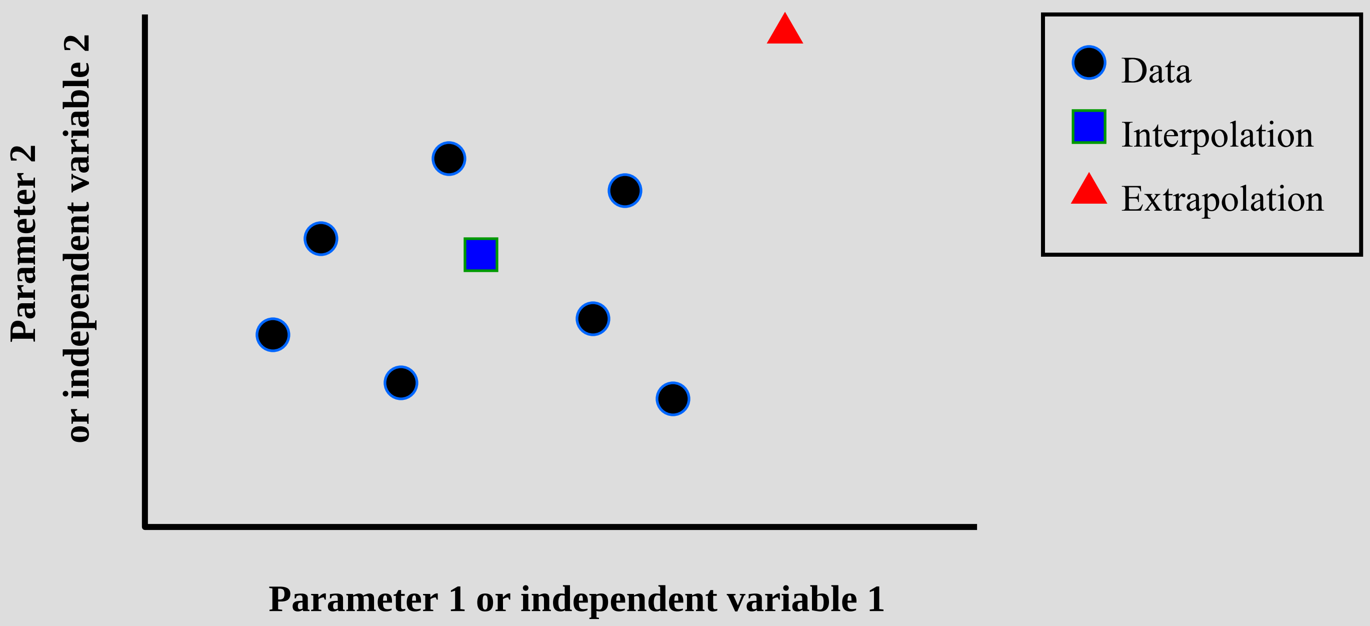
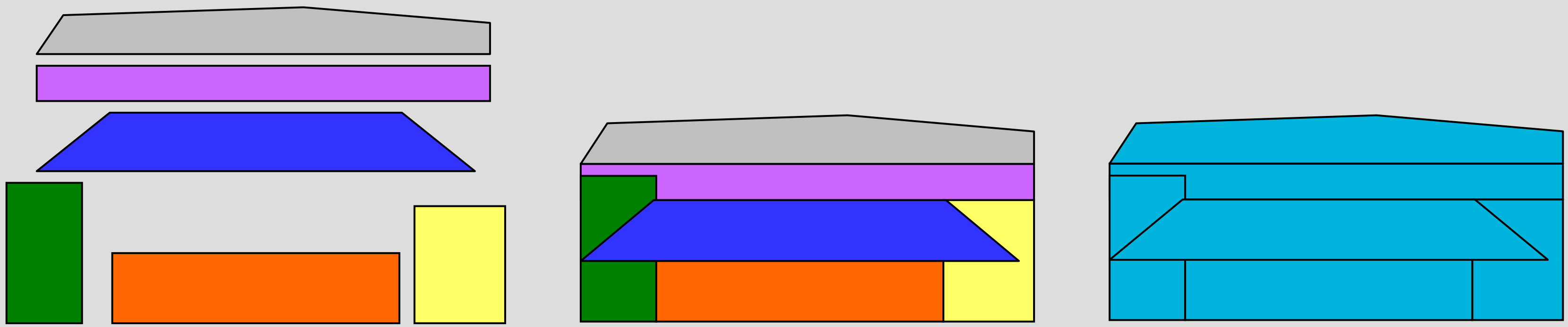
Background

- First starting in validation with support from the Nuclear Regulatory Commission in 1988
  - Validation of geosphere transport models (multiple order of magnitude variation in transport properties)
- Support from Sandia starting in 1999
  - Engineering/Physics models
- Approx. 75 publications, reports, and presentations related to validation methodology, experiments, and models
- Other efforts include
  - Validation Challenge Workshop and Special Issue of Computer Methods in Applied Mechanics
  - Principle organizer for other conference sessions and workshops for NRC and DoD on validation
  - ASME Codes and Standards committee on V&V (thermal/fluids)

Interpolation/Extrapolation of Validation Results



Subsystem to System Extrapolation



Subsystem Experiments | Combined Results | System

Different conditions for the application than those measured at the subsystem level

Partial or incomplete physics at subsystem level

Incomplete interaction between physics at subsystem level

Question: How do we relate validation results at the subsystem level to the systems level application?

Present Research Focus

- Developing extrapolation methods that preserve behavior of the application model relative to parameters and independent variables

- Approach based on ideas from geophysical inverse theory
  - Extrapolation based on the computational models for the validation experiments and the application and not on approximation models such as linear/quadratic interpolation/extrapolation or Gaussian Process surfaces
  - Trade-off between ability to resolve the application using the validation results and uncertainty in prediction can be quantified
  - Can assess ‘coverage’ of the application by the validation experiments and characterize impact

- Approach can easily be modified to preserve application model behavior relative to dimensionless groups (Π groups) without prior knowledge of these groups

- Approach can be modified to incorporate model correction terms

Example: Transient Heat Conduction

Experiment:

$$\rho C_p \frac{\partial T}{\partial t} = k \frac{\partial^2 T}{\partial x^2}$$

$T(x,0)=0$
$T(0,t) = T_1$
$T(1,t) = T_2$
$\gamma_1 = T(0.25,t_j), \quad j=1, \ldots, n$
$\gamma_2 = T(0.75,t_j), \quad j=1, \ldots, n$

Application:

$$\rho C_p \frac{\partial T}{\partial t} = k \frac{\partial^2 T}{\partial x^2}$$

$T(x,0)=0$
$T(0,t) = T_1$
$T(1,t) = T_2$
$d = -\partial \mathrm{T}(1,t_a)/\partial \mathrm{x}$

Parameters:

Experiment:

Important: T_0, T_1, $k/\rho C_p$
Uncertain: $k/\rho C_p$

Application:

Important: T_0, T_1, $k/\rho C_p$
Uncertain: T_0, T_1, $k/\rho C_p$

Example Results

t	σ_{data}	$\sigma_{\text{val-model}}$	$\sigma_{\text{app-model}}$	σ_{total}
0.125	316.746	22.627	3.988	317.579
0.250	13.485	0.487	3.132	13.853
0.375	12.920	0.451	2.884	13.245
0.500	6.639	0.211	2.837	7.222
0.625	3.380	0.113	2.830	4.409
0.750	1.291	0.041	2.829	3.110
0.875	0.621	0.022	2.828	2.896
1.000	0.386	0.008	2.828	2.855
10.00	0.410	0.000	2.828	2.858
100.0	0.410	0.000	2.828	2.858

Related Areas of Interest

- Practical issues
  - Computationally efficient methods and simplified approaches
  - Conservative models and bounds
  - Epistemic uncertainty

- Interaction between calibration and validation
  - Coupling present approach with model correction ideas from Bayesian analysis